

# for the study of the short range internal structure of the deuteron

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## Abstract

In recent time the deuteron structure at short distances is often treated from the point of view nonnucleonic degrees of freedom. In this paper the measurements of  $T$ -odd polarization observables using tensor polarized deuteron beam and polarized proton target or proton polarimeter are proposed to search the quark configurations inside the deuteron.

## 1 Introduction

Recent experimental results concerning the structure of the deuteron have led to the speculations that manifestation of the quark-gluon degrees of freedom are present even at relatively large distances between nucleons. Measurements of the cross section of the inclusive deuteron breakup  $A(d, p)X$  reaction on carbon with the proton emitted at a zero degree [1] have shown the relatively broad shoulder at internal nucleon momenta  $k \sim 0.35$  GeV/c in the deuteron defined in the light-cone dynamics [2]-[4]. This enhancement has been observed later at different initial energies and for different  $A$  values of the target [5]-[7]. This shoulder could not be reproduced by the calculations within relativistic impulse approximation (IA) using the standard deuteron wave functions [8, 9, 10], as well as by the inclusion of the rescattering corrections [11]. Theoretical work of Kobushkin and Vizireva led to the possibility of existing of a  $6q$  admixture in the deuteron wave function [12]. This  $6q$  amplitude, arising from the  $S$  configurations of six quarks, must be added to the  $S$  component of the standard deuteron wave function (DWF) with a relative phase,  $\chi$ . The fit of the experimental data [5] gave the probability of the  $6q$  configuration about  $\sim 4\%$  and relative angle  $\chi \sim 82^\circ$  and  $\sim 61^\circ$  for Paris [8] and Reid Soft Core (RSC) [9]  $NN$  potentials, respectively. Admixture of a  $6q$  state of about 3.4% was imposed also in [13] to describe the tail of momentum spectrum of the  $^{12}C(d, p)X$  reaction [5].

One of the important features of this hybrid wave function is that an additional  $6q$  admixture masks the node of the  $NN$   $S$  wave, what drastically reflects on the behaviour of polarization observables. For instance, the data on tensor analyzing power  $T_{20}$  and cross section in inclusive deuteron breakup at zero degree and at 2.1 GeV of the initial energy obtained at Saclay [7] were explained by the hybrid wave function with  $\sim 4\%$  of  $|6q\rangle$  configuration probability with  $55^\circ$  of relative phase between  $|6q\rangle$  and  $S$  component from RSC potential [9].

Recent measurements of tensor analyzing power  $T_{20}$  for deuteron inclusive breakup at  $0^\circ$  performed in Saclay [7] and in Dubna [14, 15, 16] at different energies and for different targets have shown the strong deviation from the IA predictions at  $k \geq 0.2$  GeV/c. The behaviour of the polarization transfer coefficient from vector polarized deuteron to proton  $\kappa_0$  [17, 18, 19] also disagrees with the calculations using conventional DWFs at  $k \geq 0.2$  GeV/c. On the other hand, both  $T_{20}$  and  $\kappa_0$  data demonstrate a weak dependence on  $A$  value of the target, as well as an approximate energy independence, i.e. features of IA. Considering of the mechanisms additional to IA [20, 21] can not explain the experimental data.

Most intriguing feature of the experimental data is that tensor analyzing power  $T_{20}$  in deuteron inclusive breakup and deuteron–proton backward elastic scattering show at high internal momenta of proton the same negative value  $\sim -0.3 \div -0.4$  [15, 16, 22], incompatible with the predictions using any reasonable nucleon–nucleon potential. Various attempts were undertook to explain the  $T_{20}$  data taking into account the nonnucleon degrees of freedom in the deuteron. An asymptotic negative limit of  $T_{20}$  was obtained in framework of the QCD motivated approach [23] based on reduced nuclear amplitude method [24]. The results of calculations [20] with the hybrid DWF [25] allowed to describe satisfactory the  $T_{20}$  data up to  $k \sim 1$  GeV/c [15]. Recently the data on  $T_{20}$  and  $\kappa_0$  in the  $^{12}\text{C}(d, p)X$  reaction at  $0^\circ$  were reasonably reproduced within a model which incorporates multiple scattering and Pauli principle at the quark level [26]. The additional account of the negative parity nucleon resonance exchanges improves the accordance of calculations with the experimental data on  $T_{20}$  in backward elastic  $dp$  scattering [27]. The tensor analyzing power  $A_{yy}$  in deuteron inclusive breakup obtained up to 600 MeV/c of a proton transverse momenta [28] also disagrees with the calculations within hard scattering model [29] using conventional DWFs. However, the sign of  $A_{yy}$  at large proton momenta as at a zero angle [14, 15, 16]<sup>1</sup>, as well as at a  $\sim 90^\circ$  in the rest frame of the deuteron [28] is the same as predicted by QCD motivated approach [23].

These peculiarities of the experimental data and relative successful attempts to describe them by the considering of the nonnucleon degrees of freedom stimulate to measure additional polarization observables crucial to the quark degrees of freedom in the deuteron.

In our previous paper [30] we have considered the using of the polarized proton target and proton polarimeter to study the deuteron structure at short distances. Here we propose to study  $T$ -odd polarization observables [31] in deuteron exclusive breakup in the collinear geometry and  $dp$  backward elastic scattering in order to identify the exotic  $6q$  configurations inside the deuteron.

## 2 Matrix elements of the $dp \rightarrow ppn$ and $dp \rightarrow pd$ reactions

In this section we analyze the polarization effects in two processes : deuteron breakup in the strictly collinear geometry,  $d + p \rightarrow p(0^\circ) + p(180^\circ) + n$ , and deuteron–proton backward elastic scattering,  $d + p \rightarrow p + d$ , using the hybrid DWF with the complex  $6q$  admixture.

This function can be presented in the momentum space in the following form:

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<sup>1</sup>At a zero angle emission angle  $A_{yy} = -T_{20}/\sqrt{2}$

$$\Phi_d(\mathbf{p}) = \frac{i}{\sqrt{2}} \frac{1}{\sqrt{4\pi}} \psi_p^{\alpha+} \left[ \left( U(p)(\vec{\sigma} \cdot \vec{\xi}) - \frac{W(p)}{\sqrt{2}} (3(\hat{\mathbf{p}}\vec{\xi})(\vec{\sigma}\hat{\mathbf{p}}) - (\vec{\sigma} \cdot \vec{\xi})) \right) \sigma_y \right]_{\alpha\beta} \psi_n^{\beta+}, \quad (1)$$

where  $\psi_p$  and  $\psi_n$  are the proton and neutron spinors, respectively,  $\vec{\xi}$  is the deuteron polarization vector, defined in a standard manner:

$$\vec{\xi}_1 = -\frac{1}{\sqrt{2}}(1, i, 0) \quad \vec{\xi}_{-1} = \frac{1}{\sqrt{2}}(1, -i, 0) \quad \vec{\xi}_0 = (0, 0, 1), \quad (2)$$

$\mathbf{p}$  is the relative proton–neutron momentum inside the deuteron,  $\hat{\mathbf{p}} = \mathbf{p}/|\mathbf{p}|$  is the unit vector in the  $\mathbf{p}$  direction. Here  $S$  and  $D$  components are defined as

$$\begin{aligned} U(p) &= u(p) + v_o(p) \cdot e^{i\chi}, \\ W(p) &= w(p) + v_2(p) \cdot e^{i\chi}, \end{aligned} \quad (3)$$

where  $u(p)$  and  $w(p)$  are  $S$  and  $D$  components of the standard deuteron wave function based on the  $NN$  potentials;  $v_o(p) \cdot e^{i\chi}$  and  $v_2(p) \cdot e^{i\chi}$  are the complex  $6q$  admixtures to the  $S$  and  $D$  components of the standard DWF, respectively.

Using parity conservation, time reversal invariance and the Pauli principle we can write the matrix of  $NN$  elastic scattering in terms of 5 independent complex amplitudes [32] (when isospin invariance is assumed):

$$\begin{aligned} M(\mathbf{k}', \mathbf{k}) &= \frac{1}{2} \left( (a+b) + (a-b)(\vec{\sigma}_1 \cdot \mathbf{n}) \cdot (\vec{\sigma}_2 \cdot \mathbf{n}) + \right. \\ &+ (c+d)(\vec{\sigma}_1 \cdot \mathbf{m}) \cdot (\vec{\sigma}_2 \cdot \mathbf{m}) + \\ &+ \left. (c-d)(\vec{\sigma}_1 \cdot \mathbf{l}) \cdot (\vec{\sigma}_2 \cdot \mathbf{l}) + e((\vec{\sigma}_1 + \vec{\sigma}_2) \cdot \mathbf{n}) \right), \end{aligned} \quad (4)$$

where  $a$ ,  $b$ ,  $c$ ,  $d$  and  $e$  are the scattering amplitudes,  $\vec{\sigma}_1$  and  $\vec{\sigma}_2$  are the Pauli  $2 \times 2$  matrices,  $\mathbf{k}$  and  $\mathbf{k}'$  are the unit vector in the direction of the incident and scattered particles, respectively, and center-of-mass basis vectors  $\mathbf{n}$ ,  $\mathbf{m}$ ,  $\mathbf{l}$  are defined as:

$$\mathbf{n} = \frac{\mathbf{k}' \times \mathbf{k}}{|\mathbf{k}' \times \mathbf{k}|}, \quad \mathbf{l} = \frac{\vec{\mathbf{k}}' + \mathbf{k}}{|\mathbf{k}' + \mathbf{k}|}, \quad \mathbf{m} = \frac{\mathbf{k}' - \mathbf{k}}{|\mathbf{k}' - \mathbf{k}|}. \quad (5)$$

However, at a zero angle there are only 3 independent amplitudes and the matrix element (4) can be written as [32]

$$\mathcal{M}(0) = \frac{1}{2}(A + B(\vec{\sigma}_1 \cdot \vec{\sigma}_2) + C(\vec{\sigma}_1 \cdot \mathbf{k})(\vec{\sigma}_2 \cdot \mathbf{k})), \quad (6)$$

where amplitudes  $A$ ,  $B$  and  $C$  are related to the amplitudes defined in ref.[32] as follows

$$A = a(0) + b(0), \quad B = c(0) + d(0), \quad C = -2d(0). \quad (7)$$

We consider deuteron breakup reaction in the special kinematics, i.e. with the emission of the spectator proton at zero angle, while the neutron interacts with the proton target and the products of this interaction go along the axis of the reaction.

Using of both (1) and (6) expressions the matrix element of deuteron breakup process in collinear geometry can be written as [30]

$$\begin{aligned} \mathcal{M} = & \frac{i}{2\sqrt{2}} \frac{1}{\sqrt{4\pi}} \psi_1^+ \psi_2^+ \left[ \left( U(p)(\vec{\sigma} \cdot \vec{\xi}) - \frac{W(p)}{\sqrt{2}} (3(\hat{\mathbf{p}}\vec{\xi})(\vec{\sigma}\hat{\mathbf{p}}) - (\vec{\sigma} \cdot \vec{\xi})) \right) \sigma_y \right] \times \\ & \times (A + B(\vec{\sigma}_1, \vec{\sigma}_2) + C(\vec{\sigma}_1, \mathbf{k})(\vec{\sigma}_2, \mathbf{k})) \psi_1^* \psi_2. \end{aligned} \quad (8)$$

The matrix element of  $dp$  backward elastic scattering within framework of one nucleon exchange has the following form

$$\begin{aligned} \mathcal{M} = & \frac{1}{8\pi} \psi_f^+ \left( U^*(p)(\vec{\sigma}_f \cdot \vec{\xi}_f^*) - \frac{W^*(p)}{\sqrt{2}} (3(\hat{\mathbf{p}}\vec{\xi}_f^*)(\vec{\sigma}_f\hat{\mathbf{p}}) - (\vec{\sigma}_f \cdot \vec{\xi}_f^*)) \right) \times \\ & \times \left( U(p)(\vec{\sigma}_i \cdot \vec{\xi}_i) - \frac{W(p)}{\sqrt{2}} (3(\hat{\mathbf{p}}\vec{\xi}_i)(\vec{\sigma}_i\hat{\mathbf{p}}) - (\vec{\sigma}_i \cdot \vec{\xi}_i)) \right) \psi_i \end{aligned} \quad (9)$$

### 3 Six-quark configurations

In this section we consider different models considering the quark (or baryon–baryon) degrees of freedom inside the deuteron.

In the hybrid model of the DWF [12] the  $6q$  amplitude, arising from the  $s^6$  configurations of six quarks, must be added to the  $S$  component of the standard DWF according the following expression

$$U(k) = \sqrt{1 - \beta^2} \cdot u(k) + \beta \cdot v_0(k) \cdot e^{i\chi}, \quad (10)$$

where parameter  $\beta$  and phase  $\chi$  represent value of  $6q$  admixture in deuteron and the degree of non-orthogonality between  $np$  and  $6q$  components of the DWF, respectively.

The  $6q$  admixture has the following form

$$v_0(k) = I\sqrt{10} \cdot 2^{2/3} \left( \frac{2}{1 + \sqrt{2}} \right)^6 \left( \frac{2}{3\pi\omega} \right)^{3/4} e^{-k^2/3\omega} \quad (11)$$

Factor  $I \approx 0.332$  is the overlap factor of color spin–isospin wave fuctions and  $\omega$  defines the root-mean-square radius of the  $6q$  configuration  $r^2 = 5/4\omega$ ,  $k$  is internal momentum of a nucleon in the deuteron defined in the light-cone dynamics [2]–[4].

The parameters of the  $6q$  admixture  $r$ ,  $\beta$  and  $\chi$  were obtained in [33] from the fit of the experimental data on the momentum density of the nucleon in deuteron  $\phi^2(k)$  [5], tensor analyzing power  $T_{20}$  [16] and polarization transfer coefficient  $\kappa_0$  [17, 18, 19] for deuteron inclusive breakup reaction with the emission of the proton at a zero angle using standard DWFs [8, 9, 10]. The results of the fit are given in Table 1 and shown in Fig.1 by the solid, dashed and dotted lines for RSC [9], Paris [8] and Bonn (version C) [10] DWFs, respectively. One can see the satisfactory description of the experimental data. The probability of the  $6q$  admixture is found to be 3 – 4%. The relative phase is  $\sim 40^\circ$  for RSC [9] and Paris [8] DWFs and  $55^\circ$  for Bonn C DWF [10]. The radius is  $r \sim 0.6$  fm for all used DWFs. The parameters are comparable with the results obtained in [7] using RSC DWF [9].

In [20, 25] the nonnucleon degrees of freedom ( $NN^*$ ,  $NN\pi$  and higher components of the Fock space) were taken into account in the following way

$$\Phi^2(\alpha, k_t) = (1 - \beta^2)\phi_{NN}^2(\alpha, k_t)/(2\alpha(1 - \alpha)) + \beta^2 G_d(\alpha, k_t), \quad (12)$$

where  $\Phi^2(\alpha, k_t)$  is the distribution of constituents in the deuteron;  $\phi_{NN}^2(\alpha, k_t)$  is the relativized standard DWF;  $G_d(\alpha, k_t)$  is the distribution of  $NN^*$ ,  $NN\pi$  ..., or  $6q$  component in the deuteron. Parameter  $\beta^2$  gives the probability of this nonnucleon component. The relativistic form of the DWF  $\phi_{NN}(\alpha, k_t)$  can be written according [2]-[4] as

$$\phi_{NN}(\alpha, k_t) = \left( \frac{m_p^2 + k_t^2}{4\alpha(1 - \alpha)} \right)^{1/4} \phi(k), \quad (13)$$

where  $\phi(k)$  is the standard DWF (for instance, [8, 9, 10]) and internal momentum  $k$  and longitudinal momentum fraction  $\alpha$  are defined as [2]-[4]

$$\begin{aligned} k^2 &= \frac{m_p^2 + k_t^2}{4\alpha(1 - \alpha)} - m_p^2, \\ \alpha &= \frac{k_{||} + \sqrt{k_{||}^2 + m_p^2}}{2\sqrt{k_{||}^2 + m_p^2}}. \end{aligned} \quad (14)$$

Here  $k_{||}$  is the longitudinal momentum in infinite momentum frame and  $m_p$  is the nucleon mass.

The expression for nonnucleon component  $G_d(\alpha, k_t)$  is written as [25]

$$G_d(\alpha, k_t) = b^2/(2\pi)G_1(\alpha)e^{-bk_t} \quad (15)$$

with

$$G_1(\alpha) = \Gamma(A_2 + B_2 + 2)/(\Gamma(A_2 + 1)\Gamma(B_2 + 1))\alpha^{A_2}(1 - \alpha)^{B_2}, \quad (16)$$

where  $\Gamma(\dots)$  denotes the  $\Gamma$ -function. The parameter  $b$  is chosen to be 5 GeV/c. We assume, that nonnucleon component (15)-(16) has the relative phase  $\chi$  with the  $S$  wave of the standard DWF [20].

The results of the fit of the experimental data [5, 16, 17, 18, 19] are given in Table 2 and shown in Fig.2 by the solid, dashed and dotted lines for RSC [9], Paris [8] and Bonn (version C) [10] DWFs, respectively. The probability of the nonnucleon component is found to be also  $\sim 3\%$ . The relative phase  $\chi$  between  $NN$  and nonnucleon components is  $40 - 60^\circ$ . The parameters  $A_2$  and  $B_2$  are found to be approximately the same for Paris [8], RSC [9] and Bonn C [10] DWFs. Note, all the used  $NN$  DWFs provide satisfactory agreement with the existing data, however, the using of RSC DWF gives better description of the polarization transfer coefficient  $\kappa_0$ .

## 4 T-odd polarization effects

Let us define the general spin observable of the third order in terms of Pauli  $2 \times 2$  spin matrices  $\sigma$  for protons and a set of spin operators  $S_\lambda$  for the spin 1 particle for both

reactions as [34]

$$C_{\alpha,\lambda,\beta,0} = \frac{Tr(\mathcal{M}\sigma_{\alpha}^p S_{\lambda}^d \mathcal{M}^+ \sigma_{\beta}^p)}{Tr(\mathcal{M}\mathcal{M}^+)}, \quad (17)$$

where indices  $\alpha$  and  $\lambda$  refer to the initial proton and deuteron polarization, index  $\beta$  refers to the final proton, respectively.

We use a righthand coordinate system, defined in accordance with Madison convention [35]. This system is specified by a set of three orthogonal vectors  $\vec{L}$ ,  $\vec{N}$  and  $\vec{S}$ , where  $\vec{L}$  is the unit vector along the momenta of the incident particle,  $\vec{N}$  is taken to be orthogonal to  $\vec{L}$ ,  $\vec{S} = \vec{N} \times \vec{L}$ .

In this paper we consider  $T$ -odd polarization observables, namely: tensor- vector spin correlations  $C_{N,SL,0,0}$  due to tensor polarization of the beam and polarization of the initial proton and polarization transfer coefficient  $C_{0,SL,N,0}$  from tensor polarized deuteron to proton in the  $dp \rightarrow pd$  and  $dp \rightarrow p(0^0) + p(180^0) + n$  reactions. Note, that such observables must be zero in framework of one nucleon exchange using standard deuteron wave functions, however, they do not vanish with the existing of  $6q$  admixture in the DWF.

Using the formulas for the matrix elements of the  $p(d,p)pn$  and  $p(d,p)d$  reactions (8) and (9), respectively, one can obtain the expression for the polarization transfer coefficient  $C_{0,SL,N,0}$

$$C_{0,SL,N,0} = \frac{3}{\sqrt{2}} \frac{wv_0 \sin\chi}{u^2 + w^2 + v_0^2 + 2uv_0 \cos\chi}. \quad (18)$$

One can see that  $C_{0,SL,N,0}$  does not depend on the initial energy and is defined only by the interference between  $D$  wave of the standard DWF and  $6q$  admixture. The results of the calculations with the use of Paris [8], RSC [9] and Bonn C [10] DWFs are presented in Fig. 3 *a*, *b* and *c* for two different models of the  $6q$  admixture: [12] and [20, 25] given by the solid and dashed lines, respectively. These two types of the hybrid DWFs give quite similar behaviour of the  $C_{0,SL,N,0}$  up to  $k \sim 800$  MeV/c, however, they differ at higher momenta. Both models predict the smooth variation of the  $C_{0,SL,N,0}$  of about  $-1$  at  $k \sim 600$  MeV/c. The dependence on the used  $NN$  deuteron wave function occurs only at high  $k$  of about 900 MeV/c, therefore, the observation of large negative value of  $C_{0,SL,N,0}$  could indicate that quark degrees of freedom play quite important role in the deuteron at large  $k$ .

Spin correlation parameter  $C_{N,SL,0,0}$  due to tensor polarization of the beam and polarization of the initial proton for the  $dp \rightarrow p(0^0) + p(180^0) + n$  process can be written as

$$C_{N,SL,0,0} = \frac{3}{\sqrt{2}} \frac{wv_0 \sin\chi}{u^2 + w^2 + v_0^2 + 2uv_0 \cos\chi} \cdot A_{oonn}(0^0), \quad (19)$$

where  $A_{oonn}(0^0)$  is spin correlation of neutron-proton elastic scattering at a zero angle for vertically polarized particles (see notations used in [32, 30]). Therefore, the behaviour of  $C_{N,SL,0,0}$  in the  $dp \rightarrow p(0^0) + p(180^0) + n$  reaction is defined both the DWF and  $np$  elementary amplitude which is energy dependent. The calculation of  $C_{N,SL,0,0}$  for the deuteron initial energy of 2.1 GeV and 1.25 GeV using the results of phase-shift analysis performed in [36] are shown in Figs 4 and 5, respectively. One can see that  $C_{N,SL,0,0}$  is

positive at 2.1 GeV up to  $k \sim 550$  MeV/c and negative at 1.25 GeV at  $k \sim 300 \div 400$  MeV/c. The difference between two models of  $6q$  admixture shown by the solid [12] and dashed [20, 25] lines in  $a$ ,  $b$  and  $c$  figures for Paris [8], RSC [9] and Bonn C [10] DWFs is not dramatic at both energies.

Spin correlation parameter  $C_{N,SL,0,0}$  in deuteron–proton backward elastic scattering is given in the following form

$$C_{N,SL,0,0} = \frac{1}{\sqrt{2}} \frac{wv_0 \sin \chi \cdot ((u + v_0 \cos \chi - \sqrt{2}w)^2 + v_0^2 \sin^2 \chi)}{(u^2 + w^2 + v_0^2 + 2uv_0 \cos \chi)^2}. \quad (20)$$

The behaviour of this observable for different types of  $6q$  admixture in the DWFs is shown in Fig. 6  $a$ ,  $b$  and  $c$  for Paris [8], RSC [9] and Bonn C [10] DWFs by the solid [12] and dashed [20, 25] lines, respectively. One can see that the spin correlation  $C_{N,SL,0,0}$  has a small negative value at low  $k$ , then it approaches a minima of  $\sim -0.7 \div -0.8$  at  $k \sim 400$  MeV/c and afterwards it goes smoothly to a zero for both models of  $6q$  component. However, the use of DWFs with the  $6q$  admixture adopted in [20, 25] gives systematically more negative value of spin correlation at internal momenta of  $\geq 300$  MeV/c. The use of different  $NN$  potentials [8, 9, 10] (see Fig.6  $a$ ,  $b$  and  $c$ , respectively) gives slightly different behaviour of  $C_{N,SL,0,0}$  for both models of  $6q$  admixture. Nevertheless, one can conclude that the measurements of spin correlation  $C_{N,SL,0,0}$  in  $dp$  backward elastic scattering can help to distinguish between these two models.

Note that non-orthogonality in the deuteron wave function results in the  $T$ -invariance violation, which contradicts the experiment. However,  $NN$  and  $6q$  components can be orthogonalized following the procedure described in ref.[37]. Such a procedure only slightly changes the probability of  $6q$  admixture [37], but does not affect on the behaviour of the considered observables. For instance, the probability of  $6q$  component changes from 2.96% to 3.31% and from 3.42% to 4.17% for the models [12] and [20, 25], respectively, in the case of the use of Paris DWF [8].

The six-quark wave function of the deuteron has been calculated recently not only from  $s^6$ , but also from  $s^4p^2$  configurations [38]. Such configurations are orthogonal to the usual  $S$  and  $D$  waves in the deuteron. Tensor analyzing power  $T_{20}$  and polarization transfer coefficient  $\kappa_0$  in deuteron inclusive breakup at a zero proton emission angle have been qualitatively reproduced at large internal momenta using the results of these calculations [39]. The probability of the  $D$  wave originated from  $s^4p^2$  configurations was found to be about 0.5% (a small part of  $D$  wave probability  $\sim 6\%$ ). The results on the polarization transfer  $C_{0,SL,N,0}$  and spin correlation  $C_{N,SL,0,0}$  in  $dp$  backward elastic scattering using Paris DWF [8] and the  $6q$  projection on  $NN$  component from [39] are given in Fig.7  $a$  and  $b$ , respectively. The behaviour of these observable differ significantly from the results shown in Figs. 3 and 6. This deviation is due to presence of  $D$ - wave in six-quark wave function. The results on tensor- vector spin correlation  $C_{SL,N,0,0}$  in the reaction  $dp \rightarrow p(0^0) + p(180^0) + n$  at the initial deuteron energy of 2.1 and 1.25 GeV are shown in Fig.8  $a$  and  $b$ , respectively. The behaviour is qualitatively the same as shown in Figs. 4 and 5, however, the value of  $C_{SL,N,0,0}$  at 2.1 GeV and  $k \sim 300$  MeV/c is as twice as much than that in the case of absence of  $D$  wave.

Note, the one of interesting features of QCD is the possible existing of resonances in the dibaryon system corresponding to six-quark states which are dominantly hidden color, i.e., orthogonal to the usual  $np$  states. The rich structure in the behaviour of the tensor

analyzing power  $T_{20}$  in  $dp$  backward elastic scattering [22, 40] can be an indication of such dibaryon resonances [41].

Of course, the mechanisms additional to ONE can contribute to  $C_{N,SL,0,0}$  and  $C_{0,SL,N,0}$ . However, the calculations taking into account such mechanisms [20] show that their contribution is small at large internal momenta. Thus, the observation of a large values of  $C_{N,SL,0,0}$  and  $C_{0,SL,N,0}$  at momenta higher 600 MeV/c could be rather clear indication of the exotic  $6q$  configurations.

## 5 Conclusion

We have considered  $T$ -odd observables in deuteron exclusive breakup and  $dp$  backward elastic scattering, namely, tensor- vector polarization transfer coefficient  $C_{0,SL,N,0}$  and tensor- vector spin correlation  $C_{N,SL,0,0}$ . These observables, which are associated with the tensor polarization of the deuteron and polarization of the proton, show their sensitivity to the quark degrees of freedom in the deuteron and their spin structure. The calculations give a sizeable effects at large internal momenta, which could be measured with the existing experimental techniques.

Measurements of these observables could be performed at COSY at Zero Degree Facility (ANKE) using internal polarized target with the detection of two charged particles in case of deuteron breakup and with the detection of the fast proton in case of  $dp$  backward elastic scattering.

Such experiments could be also performed at the Laboratory for High Energies of Joint Institute for Nuclear Researches. The rotation of the primary deuteron spin could be provided by the magnetic field of the beam line upstream of the target or by the special spin-rotating magnet.

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Table 1. Parameters of the  $6q$  admixture in the hybrid model [12] for different standard DWFs [8, 9, 10].

DWF	$\beta^2$ , %	$\chi$	$r$ , $fm$
[8]	$3.42 \pm 0.09$	$47.2^0 \pm 0.6^0$	$0.578 \pm 0.009$
[9]	$4.07 \pm 0.10$	$40.1^0 \pm 0.6^0$	$0.590 \pm 0.009$
[10]	$2.79 \pm 0.09$	$55.1^0 \pm 0.7^0$	$0.595 \pm 0.010$

Table 2. Parameters of the  $6q$  admixture [20, 25] for different standard DWFs [8, 9, 10].

DWF	$\beta^2$ , %	$A_2$	$B_2$	$\chi$
[8]	$2.96 \pm 0.18$	$10.0^*$	$20.23 \pm 0.42$	$47.0^0 \pm 0.6^0$
[9]	$3.70 \pm 0.43$	$10.0 \pm 0.9$	$19.87 \pm 2.72$	$40.2^0 \pm 0.6^0$
[10]	$2.67 \pm 0.19$	$10.0^*$	$19.46 \pm 0.48$	$54.6^0 \pm 0.7^0$

\* - parameter is fixed.

## Figure captions

Fig.1. Momentum density  $\Phi^2(k)$  [5], tensor analyzing power  $T_{20}$  [16] and polarization transfer coefficient  $\kappa_0$  [17] (open squares), [18] (full triangles) and [19] (full circles and squares) versus internal momentum  $k$  in deuteron inclusive breakup with the emission of proton at  $0^\circ$ . Full, dashed and dotted lines correspond to calculations with hybrid wave function [12] using RSC [9], Paris [8] and Bonn C [10] DWFs, respectively.

Fig.2. Momentum density  $\Phi^2(k)$  [5], tensor analyzing power  $T_{20}$  [16] and polarization transfer coefficient  $\kappa_0$  [17, 18, 19] versus internal momentum  $k$  in deuteron inclusive breakup with the emission of proton at  $0^\circ$ . Full, dashed and dotted lines correspond to calculations with the wave function adopted in [20, 25] using RSC [9], Paris [8] and Bonn C [10] DWFs, respectively. The symbols are the same as in Fig.1.

Fig.3. Tensor-vector polarization transfer coefficient  $C_{0,SL,N,0}$  in deuteron exclusive breakup in the collinear geometry and  $dp$  backward elastic scattering using  $6q$  admixture adopted in [12] and [20, 25] and given by the solid and dashed lines, respectively. The curves in Figs. *a*, *b* and *c* are obtained with the use of Paris [8], RSC [9] and Bonn C [10] DWFs, respectively.

Fig.4. Tensor-vector spin correlation parameter  $C_{N,SL,0,0}$  in deuteron exclusive breakup in the collinear geometry at 2.1 GeV of the deuteron initial energy using  $6q$  admixture adopted in [12] (solid lines) and [20, 25] (dashed lines). The curves in Figs. *a*, *b* and *c* are obtained with the use of Paris [8], RSC [9] and Bonn C [10] DWFs, respectively.

Fig.5. Tensor-vector spin correlation parameter  $C_{N,SL,0,0}$  in deuteron exclusive breakup in the collinear geometry at 1.25 GeV of the deuteron initial energy using  $6q$  admixture adopted in [12] and [20, 25] and given by the solid and dashed lines, respectively. The curves in Figs. *a*, *b* and *c* are obtained with the use of Paris [8], RSC [9] and Bonn C [10] DWFs, respectively.

Fig.6. Tensor-vector spin correlation parameter  $C_{N,SL,0,0}$  in deuteron- proton backward elastic scattering using  $6q$  admixture adopted in [12] and [20, 25] and given by the solid and dashed lines, respectively. The curves in Figs. *a*, *b* and *c* are obtained with the use of Paris [8], RSC [9] and Bonn C [10] DWFs, respectively.

Fig.7. a) Tensor-vector polarization transfer coefficient  $C_{0,SL,N,0}$  in deuteron exclusive breakup in the collinear geometry and  $dp$  backward elastic scattering and b) tensor-vector spin correlation parameter  $C_{N,SL,0,0}$  in deuteron-proton backward elastic scattering using results of [39] and Paris DWF [8].

Fig.8. Tensor- vector spin correlation parameter  $C_{N,SL,0,0}$  in deuteron exclusive breakup in the collinear geometry at a) 2.1 GeV and b) at 1.25 GeV of the deuteron initial energy results of [39] and Paris DWF [8].

















